

Kennecott Copper Corporation
Western Mining Divisions
Engineering Department

TAILINGS STABILIZATION PROGRESS REPORT

INTRODUCTION

In a letter of May 25, 1966, from Mr. J. C. Kinnear, Jr. to the WMD General Managers, it was requested that a concerted effort be made to stabilize and improve their respective tailings ponds. Also by letter of June 14, 1966 from Mr. Kinnear to Mr. S. D. Michaelson, authorization was given to assign the WMD-ED Industrial Hygiene Engineer the responsibility of assisting and guiding the four Western Mining Divisions in their efforts and activities in this campaign.

As an outgrowth of interest shown by Mrs. L. B. Johnson, the President's wife, in country-wide beautification, considerable effort has been expended by numerous governmental agencies, including the Bureau of Mines, toward control and usage of solid wastes. The U. S. Bureau of Mines personnel in Salt Lake City approached Kennecott in relation to a possible study of their tailings wastes. Since considerable effort on vegetation growth in tailings had been expended by Utah State University people, Kennecott directed the Bureau of Mines Management toward a cooperative effort with Utah State University in achieving an economic method of stabilizing tailings.

To streamline the efforts by all concerned, a committee was set up to guide the activities undertaken by the separate participants in the program. The committee is comprised of one representative and an alternate from each of Utah State University, Salt Lake City office of U. S. Bureau of Mines, the Anaconda Co., and Kennecott. Messrs. Knudsen and Erskine represent Kennecott on this committee as member and alternate.

HISTORY OF TAILINGS STABILIZATION

Kennecott, realizing its responsibility toward the communities adjacent to their tailings ponds, has exerted much effort toward the control of blowing tailings. The greatest efforts have been expended by the Nevada Mines Division and Utah Copper Division.

Since 1946, Nevada Mines Division has made an effort to control the tailings on the inactive areas by use of chemicals (calcium chloride) and vegetation growth. After the first experiments however, because of the cost, the calcium chloride treatment was abandoned in favor of vegetation growth. From 1949 to 1960 contracts on acreages ranging from 27 to 648 were issued annually to cultivate, seed and irrigate many varieties of vegetation including grains, legumes, native weeds, brush and willow trees, of which some of the legumes (clover and alfalfa) and willows in the more protected areas have managed to sustain themselves. In fact, a small number of tamarisk shrubs have managed to stay alive since 1949. However, only limited success was realized at Nevada

because of damage to the seedlings from sand erosion and root exposure. The annual plantings were discontinued after 1960 because of the excessive expenditures to maintain adequate plant growth.

At the Utah Copper Division in Magna, as early as 1936, experiments with grass seed plantings were undertaken, followed later by the use of chemicals on selected test plots. Both calcium chloride and lignin sulfonate were experimented with. Because of the tailings pond encroachment on the test areas, insufficient time was available to satisfactorily evaluate their benefits. It was determined, however, that with winds around 40 miles per hour the crusted chemically treated tailings would break up and allow blowing of the exposed sands.

Past experience by others has demonstrated some success with vegetation growth in desert sands by prestabilization with emulsified asphalts, oil resins and rubber latexes. The U. S. Bureau of Mines is investigating the use of prestabilization chemicals for establishment of vegetation on tailings. A cooperative Bureau of Mines and Kennecott field test of this technique is scheduled at Nevada Mines Division for the fall of 1967.

CONCLUSIONS AND RECOMMENDATIONS

Decisive information is as yet not sufficiently complete to fully establish whether vegetation can be grown successfully in all types of tailings. There are, however, many factors that have manifested themselves toward a more knowledgeable approach in future field studies.

Closely controlled studies by the USU have shown that to promote successful seed germination, the Utah tailings must be leached to minimize salinity. In the Chino tailings the natural acidity exceeds the levels that will sustain growth of most varieties of vegetation. After leaching the acid content was lowered to a point where plant growth could be sustained. To promote growth in leached tailings, initial additions of nitrogen and phosphorous and in some cases potassium must be made. It was discovered at the Bureau of Mines, however, that by using ammonium sulfate to an excess the ammonia was believed to solubilize the copper in copper bearing tailings and this resulted in plant necrosis.

At the Utah State University after two years of continued growth in small barrels, clover was found to have successfully reseeded and upon examination of the root structure was found to have formed nitrogen fixing nodules, which is indeed most encouraging.

Since there is considerable difference between greenhouse and small controlled plot experiments and that of full scale field experiments, it was recommended that field studies under a variety of conditions be undertaken. This is in the offing on a Utah Copper Division two acre test plot at the west end of the

Utah tailings pond - now under construction. Also, additional plant growth tests are scheduled on a ten acre portion of the Nevada Mines Division dead tailings area.

PRELIMINARY PROGRAM WITH UTAH STATE UNIVERSITY

As part of a plan instigated in conjunction with the tailings test jetty constructed in the Great Salt Lake, the Great Salt Lake Authority envisioned reclaiming vast acreages of land adjacent to the Great Salt Lake with a tailings cover and the eventual ecological succession of native plant growth or even the growth of domestic crops for foraging or harvesting. Utah State University personnel exhibited an interest in the project and were later retained by the Great Salt Lake Authority to supervise the project and perform experiments on the growth of vegetation in Utah tailings. Also, at this time Kennecott's Utah Copper Division and WMD-ED personnel were invited to assist with the overall project development.

To set up the program, during 1965 numerous meetings were held with Utah State University and the Great Salt Lake Authority personnel. A truck load of tailings was delivered to the USU for the initial experimentation. Several small lots of tailings have been delivered since, including barrels of wet tailings collected directly from the flume.

The early greenhouse experiments with barley, clover, alfalfa and tall wheat grass indicated no special problem to establishing plant growth in tailings but it was later determined that there were interfering factors that prevented plant maturity in many of the plants. Also, different batches of tailings had different effects on the vegetation.

It was resolved at that time that all tailings must be analyzed and characterized so that future experiments would be more meaningful.

TAILINGS CHARACTERISTICS

As a starting point for obtaining data on the characteristics of tailings the WMD-ED Industrial Hygiene Engineer obtained auger samples at one foot intervals for a depth of four feet at Utah and Nevada - later samples were collected at Chino and Ray Mines Division for analyses. Sampling points were selected to provide as representative a set of samples as possible.

The tailings samples varied markedly not only from each division but within each respective pond.

The chemists at USU are attempting to determine if the cause of plant necrosis is due to the heavy metals, to reagents retained with the tailings, or to a complex ion of an unknown nature.

After the Bureau of Mines became sponsors of USU research, they furnished the University with many more varieties of tailings, including those from uranium mines. The attached table indicates the range of the differences encountered in the tailings sources. It is believed that the extremely low pH (reaching 2.2) of Chino Mines Division tailings is caused by oxidation of the contained pyrites. Of the copper bearing tailings analyzed, Miami Copper and San Manuel appear to have the most favorable media to foster plant growth. This may explain why Miami vegetation growth on tailings is, after five years standing, quite successful. The tailings were covered with borrowed material, mostly Gila conglomerate, to a depth of three to five inches. There is evidence by plant removal and root structure examination that root growth into the raw tailings has as yet not interfered with plant maturity as was initially feared.

COOPERATIVE APPROACH - USU, U. S. B. of MINES, ANACONDA & KENNECOTT

When the original field test plots, one adjacent to the Great Salt Lake Authority's tailings test jetty and one at the southeast corner of the Utah tailings pond, failed to be developed, a new site was selected for field studies as part of the cooperative effort among the Utah State University, the Bureau of Mines and Kennecott. This site, located at the west end of the Utah tailings pond, is easily accessible, close to good irrigation water and is protected from adverse winds. Construction on this site has begun and it is expected to be ready for planting by September, 1967.

The Utah State University was awarded a \$40,000 grant by the U. S. Bureau of Mines to study solid waste stabilization during the fiscal year 1966-67. Since all preliminary work had been done on KCC tailings, the Bureau consented to a continuation of this practice, using UCD tailings as the standard test material.

Greenhouse and small outside plot experimentation was continued but on an accelerated and more grandiose scale, applying the latest known technology toward characterizing all variables relating to plant growth.

The principal objectives of the first year's study were to delineate as far as possible the types of vegetation most amenable to growth in tailings, to determine the amendments needed to promote and sustain vegetative growth, and to ferret out the factors that deter germination and plant maturation.

Utah State University's findings to date are:

<u>Problem</u>	<u>Findings</u>
1. Tailings characteristics	1. Most tailings exhibit different characteristics and must be treated individually.
2. Range of salinity either natural or induced	2. To assure adequate seed germination, the salts, if a problem, must be leached from the tailings before seeding.

<u>Problem</u>	<u>Findings</u>
3. pH - too high, too low or changing	3. If leaching does not alter the pH sufficiently to allow proper growth, neutralization is necessary.
4. Physical properties: too fine or too coarse	4. Extremely fine tailings (slimes) were found impervious to water whereas exceedingly coarse tailings failed to retain sufficient water.
5. Specific ion toxicity	5. Insufficient data available to fully establish the causative agent or agents that interfere with plant maturity.
6. Nutrient deficiencies, if any	6. Tailings, though leached, will not in themselves sustain growth without nutrient amendments. With most tailings, nitrates and phosphates are needed. With a few the addition of potassium is necessary. These requirements are based on an analysis of individual tailings.
7. Imbalance of mineral elements	7. Most vegetation flourishes with minor amounts of minerals contained in soil, but most vegetation is intolerant to excessive amounts of zinc, iron and copper. More work is being done to establish tolerable levels.
8. Adaptable vegetation	8. Vegetation found most amenable to growth in Utah tailings is: <ul style="list-style-type: none">a. Tall wheat grassb. Intermediate wheat grassc. Crested wheat grassd. Alkali sacatone. Indian rice grassf. Sweet cloverg. Alfalfah. Sage brushi. Quack grassj. Russian thistlek. Kochio

The Bureau of Mines in separate experiments under controlled inside conditions working with prestabilization emulsions found that all the stabilizers enhanced germination and growth in tomato plants. They experimented with

S. P. 400 Latex, Penepime, Soil Guard Green and Coherex. Costwise the Coherex was found the most promising and after further experimentation may prove to be economically feasible for large scale applications on tailings.

Further experimental work is being carried out at the Salt Lake Bureau of Mines using Nevada Mines Division tailings. Outside test plots about four by five feet by eleven inches deep have been seeded with a shotgun mix of grasses under the following conditions:

1. Control - no amendments or emulsions
2. One fourth gallon Coherex per square yard
3. One fourth gallon Coherex plus an Amine
4. One half gallon Coherex per square yard
5. One fourth gallon Coherex plus urea
6. One fourth gallon Coherex plus urea and phosphates

Results of these tests to be completed by the fall of 1967, will guide procedures to be followed on a proposed 10 acre test area on Nevada's inactive tailings, scheduled for planting by fall 1967.

Since the organization of the cooperative committee to guide tailings stabilization activities, three meetings, August 6, 1966, October 24, 1966, and April 18, 1967, were held to review progress and make future plans, the outgrowth of which has led to the three plans of attack now underway. The April 1967 meeting was held in Miami, Arizona, at the invitation of Mr. B. R. Coil, General Manager, Miami Copper Co. The committee and guests inspected Miami's tailings stabilization projects at Solitude, Castle Dome and Copper Cities tailings sites. Mr. Bernard W. Benson, consulting botanist, reviewed for those in attendance the history of early attempts at stabilization, including the building of berms and flooding, seeding on raw tailings, etc., which by and large ended in failure. Until a cover of borrowed material, primarily Gila conglomerate, was placed at a depth of from three to five inches on the tailings, little success was achieved. The dirt covering cost 40¢ per cubic yard laid down. A varied mixture of seeds was planted both during the spring and fall. The mix included two varieties of African love grass, sudan grass, Bermuda grass, perennial rye grass, millet, winter barley, white oats, clover and some cottonwood and poplar seedlings. The love grasses, perennial rye and alfalfa have shown the greatest promise. There was remarkable evidence of ecological succession of the native grasses and brush. In many areas salt cedar has become established and dominates all other species. The vegetation has flourished without benefit of irrigation or fertilization. Mr. Benson emphasized

that the type of vegetation planted was immaterial because it served only the purpose of encouraging birds that carry seeds and to provide a catching media for windborne seeds from the surrounding native vegetation.

It was also made clear that reflective heat from the bare tailings played a large role in impeding plant growth - leaf temperatures were measured as high as 165° F.

At the Miami meeting, Mr. C. J. Hanson of Anaconda Company described the vegetation growth project at Twin Buttes south of Tucson, Arizona. He indicated they have experienced remarkable success with both native and domestic vegetation. However, it must be kept in mind that the tailings dam is constructed of mine overburden which minimizes the problem considerably.

To date, Miami Copper and the Twin Butte properties are the only ones in the arid climates similar to Kennecott operations that have successfully stabilized tailings areas with vegetation.

KENNECOTT PROPERTIES

Chino Mines Division

Until 1967, little was done at CMD toward tailings stabilization with vegetation mainly because blowing tailings posed no problem to the townsite. However, because of the increased interest nationally on countryside beautification and solids wastes control the local Soil Conservation Service personnel exhibited an interest toward tailings stabilization at CMD. Mr. Roy Mann of SCS was assigned the project and has cooperated fully with CMD people in plans for a vegetation test plot on a section of Chino's inactive tailings.

Three levels about 100 yards long were smoothed and terraced at about 30 foot intervals down the western slope of the north tailings pond. The terraced sections were backward sloped to retain runoff from the slopes immediately above. Mr. Mann had placed about a foot of borrowed material in a trench on one of the terraces after which three types of shrubs were planted; New Mexico Olive, Mountain Mahogany and Squaw Brush.

On June 22, 1967 a meeting was held at Chino Mines Division with representatives of the Soil Conservation Service, Kennecott's CMD and WMD-ED in attendance. The purpose of the meeting was to develop a cooperative program among the groups showing an interest in tailings stabilization, and to observe the progress made on the growth of shrubs in Chino tailings. The shrubs planted in early March, though nipped by frost, are showing some new growth. Should the root system of the shrubs show signs of necrosis after reaching the raw tailings, the plants will be uprooted and shipped to USU for study in an effort to determine the cause.

Mr. Frank Brooks, SCS Western Region, will discuss during his travels the stabilization program with other mining, forestry and highway people to ascertain new approaches to tailings stabilization. He will apprise those interested of any new discoveries.

At the "Western Society of Crop Science" Conference held in Las Cruces, New Mexico, June 28, 1967, Mr. Rex Nielson of USU discussed many of the problems they had encountered in their attempts at growing vegetation in tailings. Later in the day a conference comprised of Soil Conservation Service, Utah State University and Kennecott people was held to discuss further the more apparent problems of growing vegetation in tailings and to organize a campaign to encourage participation by other interested groups. The SCS people will, as a result of this conference, enhance their efforts at growing other varieties of vegetation in Chino tailings. The decrease in pH with time in Chino tailings was discussed at great length. To gain more knowledge on this change of pH, Mr. Rex Nielson asked that some fresh tailings be shipped to the USU for study. This will be done.

Nevada Mines Division

Over the past two years, renewed effort toward stabilizing Nevada's inactive tailings has led to trials of a method used at Anaconda, Montana, i.e., disking in straw, and in addition a test of disking in sage brush. There is some indication that, with normal wind velocities, blowing is abated in these areas but heavy winds (gusts over 40 miles per hour) lift the straw and brush along with the tailings.

Another stabilization program which looks more encouraging is the spreading of a 1-2" granulated slag layer over the tailings. Plans are to cover a larger area in the near future.

As stated earlier, NMD is cooperating with the Salt Lake office of the U. S. Bureau of Mines in a renewed attempt to grow vegetation on the inactive tailings. Five acres of a 10 acre plot scheduled for planting in the fall of 1967 will be prestabilized with "Coherex" and planting will be done in about 12 foot square paddocks formed by bordering with borrowed material. The other five acres will be left in a natural state and seeded, but with the benefit of pre-stabilization with Coherex.

Ray Mines Division

At Ray Mines Division studies are underway for instituting the peripheral discharge of tailings so as to keep the pond wetted for a greater period of time. The major blowing with heavy winds is from the area made ready for fresh tailings and from the dike roadways. Recent experiments with "Coherex" as an allaying agent on the roadways and ramps have proved most encouraging.

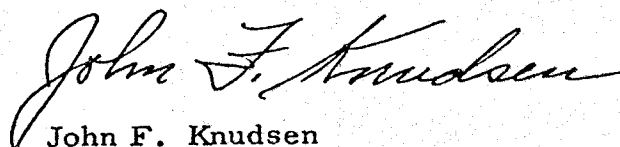
In an effort to screen the tailings pond from tourists and other passersby, eucalyptus trees have been planted on the north side of the tailings pond between the highway and the bank.

Utah State University personnel are studying samples of RMD tailings in preparation for possible future vegetation stabilization of this tailings area.

Utah Copper Division

The experimentation with chemicals and grass planting has been described in the history section of this report. Present cooperation with USU, the Great Salt Lake Authority and the Bureau of Mines is in progress. Tailings stabilization on the tailings pond has been attempted by sprinkling and furrowing of the dry areas. Sprinkling was first done from a piping system using rain-bird sprinklers but this was abandoned in favor of a large sprinkling truck now in use. Furrowing was done, both to bring moisture to the surface and to form a trough to trap tailings under moderate wind conditions, thus to prevent excessive blowing. These procedures have been partially successful.

To improve on the unsightliness, Russian Olive seedlings have been planted on the south side bank of the Utah tailings pond. This program was initiated in late 1966 and its success cannot yet be evaluated.



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Industrial Hygiene Engineer

ANALYSIS OF WATER EXTRACTS OF MINE WASTE MATERIALS

U.S.U.- Lab. No.	Collector's No. and Location	pH		Sat. Ext. Cond, KX10 ³	Moist at Sat. %	PPM										
		Paste	Extract			Al	Ba	Fe	Sr	B	Ni	Cu	Zn	Mn	Cr	Pb
U67674	Chino Hurley, N.M., Ken. Cop.	2.2	2.2	9.47	24	1100	.34	3000	<.50	10	5.3	>600	21	24	<.60	<5.0
" 75	1.0 Ken. Cop. Magna, Ut.	7.9	7.0	9.51	37	1.2	<.20	.59	2.5	.35	<2.5	.080	.15	<.20	<.60	<5.0
" 76	71.3 Anaconda Butte, Mont.	5.1	5.2	3.17	23	<1.0	<.20	.59	<.50	.35	<.25	195	238	154	<.60	<5.0
" 77	72.1 Anaconda, Mont.	8.2	7.6	2.13	23	<1.0	<.20	<.50	.64	.18	<2.5	.080	.15	.56	<.60	<5.0
" 78	75.1 Mexican Hat, Utah	2.8	2.9	8.00	29	700	.39	45	.80	1.4	78	475	103	440	1.2	16
" 79	75.2 Mexican Hat, Utah	1.9	1.9	17.4	55	1400	.56	>5000	3.7	24	39	>600	77	1005	6.5	30
" 80	121.1 Naturita, Colorado	8.2	7.8	2.26	23	<1.0	<.20	1.0	3.7	.18	<2.5	.080	.15	<.20	<6.0	<5.0
" 81	121.2 Naturita, Colorado	8.4	7.8	3.36	29	1.2	.56	.59	1.6	.35	<2.5	.22	.36	<.20	<6.0	<5.0
" 82	124.1 Union Carbide Urravan, Colo.	3.2	3.4	5.46	23	200	<.20	10	6.8	.84	4.0	25	61	31	<6.0	6.2
" 83	124.2 Union Carbide Urravan, Colo.	3.5	3.5	11.7	26	1100	<.20	9.0	.85	1.6	4.0	14	47	31	1.6	20
" 84	127.1 Durango, Colorado	8.1	8.0	5.03	24	<1.0	<.20	<.50	1.6	.31	<2.5	<.080	.15	<.20	<6.0	<5.0
" 85	647.2 San Manuel, Arizona	8.0	7.4	3.41	38	<1.0	<.20	<.50	2.9	.13	<2.5	<.080	.080	<.20	<6.0	<5.0
" 86	649.1 Miami Copper Co., Arizona	7.8	7.3	3.10	29	<1.0	<.20	<.50	<.50	.13	<2.5	<.080	.15	<.20	<6.0	<5.0

Each material was wet to point of saturation and the moisture percentage determined. The "paste" pH measurement was made of this mixture. Water was then extracted from the solids by use of "section" to obtain the extract. This was analyzed for total salt by determining the conductivity. Determination was made for the heavy metal content of the extract by Jarrell-Ash Direct Reading Spectrometer.